DEVELOPMENT OF NEW AIRBAG SYSTEM FOR REAR-SEAT OCCUPANTS

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ABSTRACT

In addition to seatbelts, most vehicles today are fitted with airbags in the front seats as restraint devices for protecting occupants in frontal collisions. However, various constraints in the rear seats have prevented progress in adopting the same type of airbag system as that used in the front seats. Therefore, a new airbag system has been developed as a crash energy absorbing device to improve protection of the head and neck of rear-seat occupants. This new airbag system can be installed under the traditional constraints present in the rear seats.

INTRODUCTION

Research on rear-seat occupant restraint systems is under way in many countries around the world today accompanying the rising concern in recent years about protection for rear-seat occupants in frontal collisions. In Japan, the Road Traffic Law was amended on June 1, 2008 to make the use of seatbelts mandatory in the rear seats as well, in addition to mandated use for the driver and front passenger. Beginning from April 1, 2009, a test procedure for evaluating rear-seat occupant protection is scheduled to be included in the New Car Assessment Program in Japan. As a result, information about rear-seat occupant safety performance will be made available to the general public.

At present, passenger vehicles are generally fitted with seatbelts and airbags in the front seats and seatbelts in the rear seats as restraint devices for protecting occupants in frontal collisions. It has been reported that the use of seatbelts by rear-seat occupants could have the effect of reducing their present levels of fatal and serious injuries by approximately one-half and their fatality rate by approximately two-thirds[1]. These figures are indicative of the effect that using seatbelts could have on improving rear-seat occupant protection.

A breakdown of the locations of fatal and serious injuries incurred by belted rear-seat occupants in frontal collisions shows that the most frequent region of the body in descending order are the chest, arms, head, legs and neck (Figure 1). For fatal injuries, in a similar way are the chest, abdomen, head and neck (Figure 2)[2].

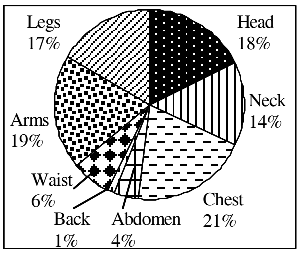


Figure 1. Location of fatal and serious injuries.

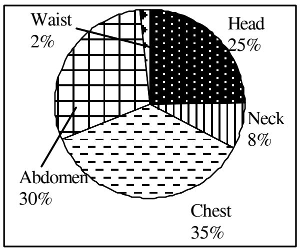


Figure 2. Location of fatal injuries.

It has been reported that, among these injury locations, seatbelt systems work to improve chest protection for rear-seat occupants[3]. However, little research has been done so far on protection for the head and neck, which account for approximately 30% of both fatal/serious injuries and fatal injuries.

The purpose of this research is to improve protection performance for the head and neck of rear-seat occupants. A new rear-seat airbag system has been developed that does not require any airbag mounting part or any reaction force support structures in front of the occupants. This makes it possible to install the system even under the traditional constraints present in the rear seats. This paper presents an outline of the new airbag system, an analysis of bag deployment behavior and the results of sled tests conducted to confirm the effect of the system on reducing occupant injury levels.

OVERVIEW OF NEW AIRBAG SYSTEM

Structure

In order for an airbag to absorb an occupant's kinetic energy, the bag must be supported so that it can generate reaction force toward the occupant when it receives force from the occupant. In the front seats, the steering wheel, steering column and instrument panel are among the forward parts that can serve to support the airbags, enabling them to absorb the occupants' kinetic energy.

In contrast to that situation, the rear-seat airbag system described here generates reaction force by deploying two airbags in the area between an occupant's head and thighs when the occupant's upper body tilts forward in a frontal collision. This mechanism serves to absorb the occupant's kinetic energy.

The shoulder belt cover and lap belt cover of a three-point seatbelt system each house one airbag. In the event of a frontal collision, the bags split the covers in the process of deploying in front of an occupant (Figure 3).

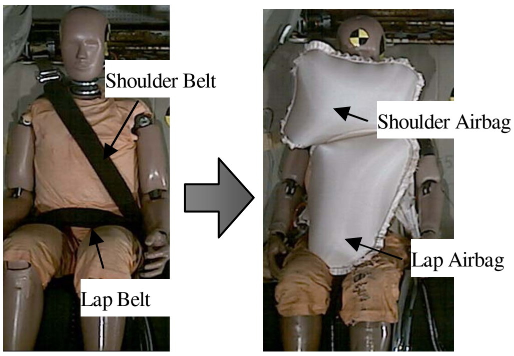


Figure 3. The bags deploy and split the covers in front of an occupant.

Gas is supplied from an inflator incorporated in the buckle to the shoulder belt airbag through a pipe built into the tongue. For the lap belt airbag, gas is supplied directly to the bag from an inflator positioned at the side of the seatbelt anchor (Figures 4, 5).

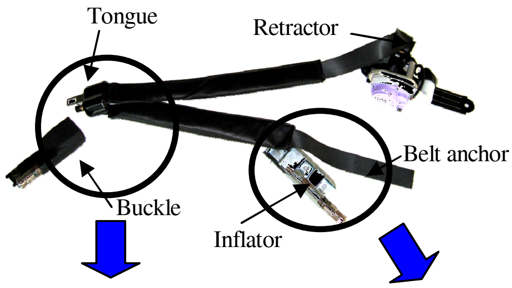


Figure 4. System overview.

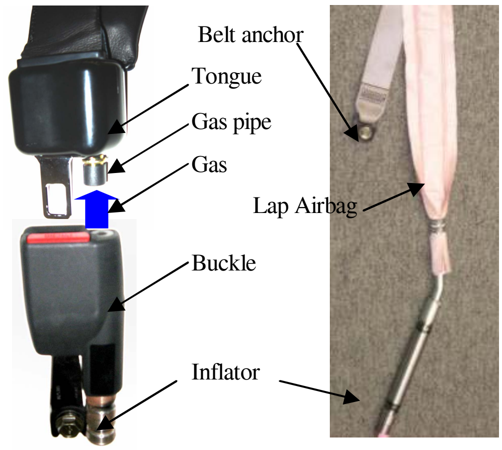


Figure 5. Buckle, tongue and belt anchor.

Airbag impact tests

Airbag impact tests were conducted to confirm the ability to supply sufficient gas pressure to the bags and the reaction force characteristics of the bags themselves. The two airbags and the gas supply mechanism were secured to a wall, and gas was supplied to the bags using the same system configuration as that installed in a vehicle. The bags were struck with an impactor when they were fully deployed. The impact test results confirmed that the necessary airbag internal pressure could be secured and that the bags did not tear or suffer any other damage. (Figures 6)

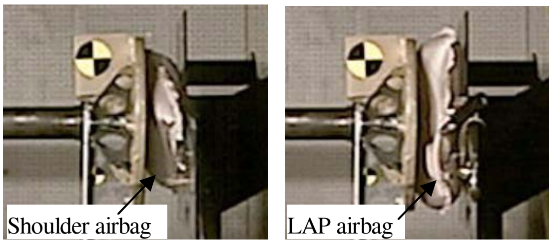
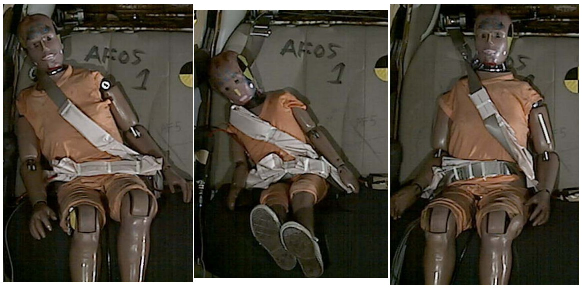


Figure 6. Airbag impact tests.

Static deployment tests

Static airbag deployment tests were conducted using belted Hybrid-III AF05 and 6YO crash test dummies seated in the rear seats. The purpose of these tests was to investigate the influence of airbag deployment under a condition with belted rear-seat occupants. The test setup in Figure 7 left and center shows the dummies leaning against the door and window with the shoulder belt resting on their neck.



AF05 dummy 6YO dummy belts semi-twisted

Figure 7. Static deployment tests conditions.

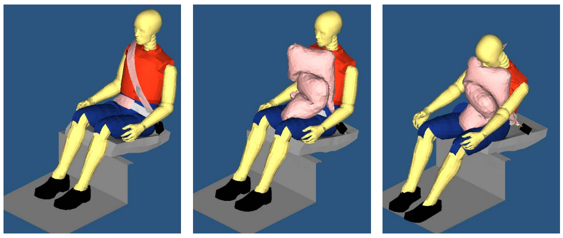
This situation represents the slumping posture of rear-seat occupants. The setup in Figure 8 right simulates a situation where the belts are worn incorrectly in a semi-twisted condition, with the result that the bags are deployed between the dummy and the belts. The results of both of these static deployment tests showed injury levels that would not be any problem from the standpoint of occupant protection.

SIMULATION STUDY OF AIRBAG DEPLOYMENT BEHAVIOR

Confirmation of bag behavior for head support

As described in the preceding section, this airbag system is designed to restrain a rear-seat occupant in a frontal collision by deploying two airbags from the lap and shoulder belts in the area between the head and thighs. With this mechanism, it is important for the two airbags to come together without missing one another in the deployment process, so as to provide stable support for an occupant's head.

In order to verify that deployment behavior, simulations were conducted with the MADYMO (Mathematical Dynamic Models) to confirm airbag behavior and the effect of the system on reducing occupant injury levels. The simulations were performed by varying the inflator output, deployment timing and other parameters. The MADYMO simulation model is shown in Figure 8 at different elapsed times.



0 msec 35 msec 75 msec

Figure 8. Sled test simulation model (MADYMO)

A simulation conducted using the final test specifications showed that an occupant's head would be supported by the two bags and that the airbag internal pressure was higher than the level in the bag deployment tests. Figures 9 and 10 compare the internal pressure of the shoulder belt airbag and lap belt airbag, respectively, when the pressure was normalized to the level in the bag deployment tests.

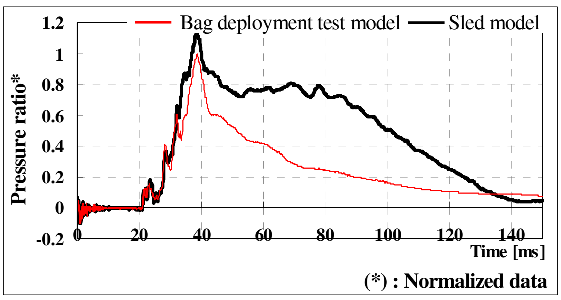


Figure 9. Comparison of the shoulder airbag internal pressure, bag deployment test model and sled model.

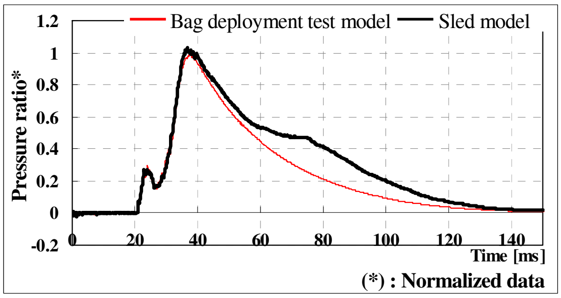


Figure 10. Comparison of the lap airbag internal pressure, bag deployment test model and sled model.

SLED TESTS

Sled test method

Sled tests were conducted to confirm the effect of the specifications obtained in the MADYMO simulations on improving rear-seat occupant protection. Hybrid-III AM50 crash test dummies were seated in the right and left rear seats of the sled with and without the new rear-seat airbag system, with the same type seatbelt with a pretensioner and a loadlimitter, and tests were conducted under conditions corresponding to a full-overlap frontal collision at a speed of 56 km/h. The results were then compared to confirm the effect of the system on reducing occupant injury levels.

Sled test results

<u>**Head injury level**</u> - Head acceleration (G) values in the x- and z-axis directions and the 3-axis resultant values obtained in the sled tests with and without the new airbag system are compared in Figures 11, 12 and 13, respectively. The head acceleration values were normalized to the peak values recorded without the airbag system.

In Figure 11, it is seen that head acceleration in the x-axis direction in the interval from 40 ms to 110 ms was higher with the airbag system than without it, owing to the reaction force generated by contact between the head and the shoulder belt airbag. The peak value with the airbag system was 31% higher than that without the system.

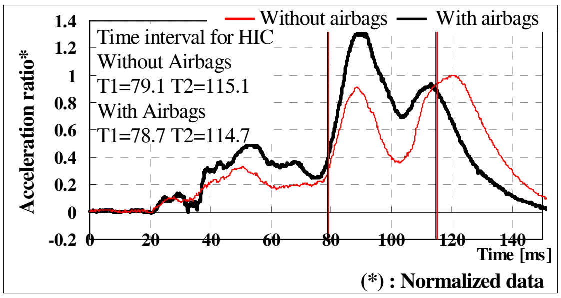


Figure 11. Comparison of the head G in x-axis direction, with and without airbags.

Similarly, in Figure 12, head acceleration in the z-axis direction was higher with the airbag system than without it in the 40-70 ms interval. During that initial period when the dummy leaned forward, the head was supported at the front from below by the airbags. However, in the latter period from 80 ms to 130 ms when the shoulder belt airbag suppressed the turning motion of the head, acceleration induced by centrifugal force decreased(Figure 13). The peak value with the airbag system was 23% lower than that without it.

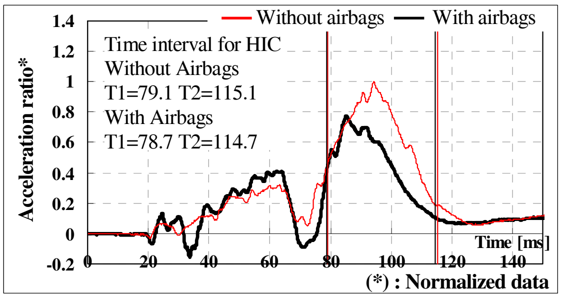


Figure 12. Comparison of the head G in z-axis direction, with and without airbags.

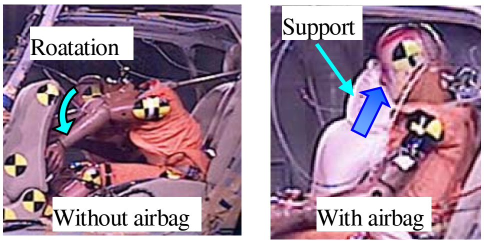


Figure 13. Comparison of the turning motion of the head.

As a result, after 80 ms the 3-axis resultant acceleration was lower with the airbag system than without it, although the former value was higher than the latter one in the initial impact interval from 40 ms to 70 ms

(Figure 14). The peak value with the airbag system was 10% lower in the latter period, and the system had the effect of reducing the head injury criterion HIC36 value by 26% .

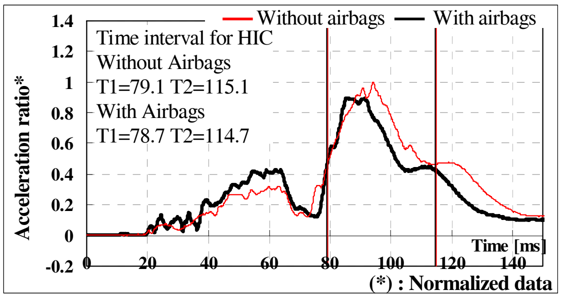


Figure 14. Comparison of the head resultant G, with and without airbags.

The dummy's behavior without and with the airbag system at three elapsed times is compared in Figure 15, respectively.

60 msec **90 msec** **120 msec**

Without airbags

60 msec **90 msec** **120 msec**

With airbags

Figure 15. Comparison of the dummy's behavior, with and without airbags.

Neck injury level - The shear load Fx, tensile load Fz and bending moment My of the neck recorded with and without the airbag system are compared in Figures 16, 17, and 18, respectively. The injury levels have been normalized to the peak values without the airbag system.

Without the airbag system the neck shear load Fx was caused by shearing action between the dummy's upper body and the head and neck. The forward motion of the former was stopped by the shoulder belt while the latter tried to continue to move forward due to the inertial mass. In contrast, the results with the airbag system show a large reduction in Fx after 60 msec because the forward movement of the head was restrained by the airbags. The peak value of Fz was 30% lower than the value recorded without the airbag system(Figure 16).

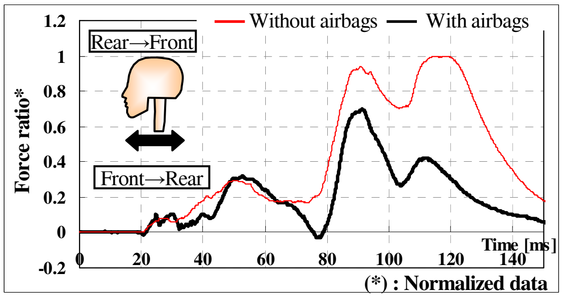


Figure 16. Comparison of the neck UPR shear force (N), with and without airbags.

The neck tensile load Fz was higher with the airbag system than without it in the 40-70 msec intervals because the head was supported at the front from below by the airbags in this initial period when the dummy leaned forward. This result is similar to that mentioned above regarding the acceleration of the head in the z-axis direction. However, Fz was lower with the airbag system than without it after 70 ms because the airbags worked to suppress the turning motion of the head, which reduced the tensile load due to centrifugal force. The system reduced the peak value of Fz by 7% compared with the result without the airbag system(Figure 17).

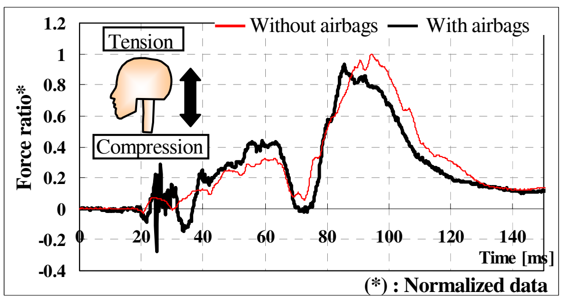


Figure 17. Comparison of the neck UPR tensile force (N), with and without airbags.

The neck bending moment My without the airbag system showed a larger peak on the negative side owing to a moment in the extension direction that occurred when the lower neck was lifted upward by the upthrust load induced by the bottoming out of the pelvis. The forward movement of the dummy's upper body was stopped by the shoulder belt while the head was bent downward. In contrast, with the airbag system, the airbags supported the head at the front from below, which reduced the forward flexion of the head in the 60-75 ms interval. The upthrust load became a compressive load component in the z-axis direction of the neck, thereby suppressing the increase in the moment in the extension direction, and the peak value of My was reduced by 49%. In addition, following the peak on the flexion side around 100 ms, the airbags supported the head, which suppressed the amount of flexion and the peak value was reduced by 17% compared with the result recorded without the airbag system(Figure 18).

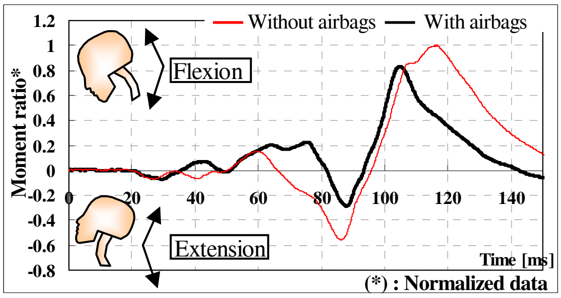


Figure 18. Comparison of the neck UPR bending moment in y-axis direction (Nm), with and without airbags.

CONCLUSION

This paper has described a newly developed rear-seat airbag system that is designed to provide improved protection performance for the head and neck, which together account for approximately 30% of the fatal injuries incurred by rear-seat occupants in frontal collisions. This system does not require any airbag mounting part or reaction force support structure in front of the rear-seat occupants, making it possible to install the system even under the traditional constraints present in the rear seats.

Sled tests conducted with a prototype model of the new airbag system confirmed that it is effective in reducing occupant injury levels. The following results were obtained in the tests.

- The new airbag system restrains an occupant's head and absorbs its kinetic energy, thereby suppressing the centrifugal force resulting from the turning motion of the head and reducing head injury levels.
- By suppressing the turning motion of the head, the new airbag system is also effective in reducing neck injury levels in terms of the shear load, tensile load and bending moment.

The present prototype system houses the airbags inside the covers of the shoulder and lap belts, making the belts stiffer and heavier and thus detracting from their ease and comfort of use. These are aspects that must be examined in future work. It will be necessary to examine ways of weight reduction of the airbags and making them thinner when folded up inside the belt covers, without sacrificing their deployment performance.

ACKNOWLEDGMENTS

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